Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT A05C0187

LOSS OF CONTROL AND COLLISION WITH TERRAIN

MORNINGSTAR AIR EXPRESS INC.
CESSNA 208B CARAVAN C-FEXS
WINNIPEG, MANITOBA
06 OCTOBER 2005

Canada

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Synopsis

The Morningstar Air Express Inc. Cessna 208B Caravan (registration C-FEXS, serial number 208B0542), operating as MAL8060, departed from Winnipeg, Manitoba, on a freight flight to Thunder Bay, Ontario, with one pilot on board. The aircraft departed at 0537 central daylight time. Shortly after take-off, the flight was cleared to 9000 feet above sea level and direct to Thunder Bay. Several minutes later, the aircraft began a descent and the pilot requested an immediate return to the Winnipeg International Airport. The aircraft turned right to a southwesterly heading, and then the descent continued below radar coverage. After a very steep descent, it crashed on railway tracks in Winnipeg. The pilot suffered fatal injuries, and the aircraft was destroyed by impact forces and an intense post-crash fire.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

On the day before the occurrence, the accident aircraft arrived in Winnipeg, Manitoba, on a flight from Thunder Bay, Ontario. The aircraft was parked in a heated hangar overnight and was pulled outside at about 0410 central daylight time.[1] The pilot reviewed the weather information and completed planning for the flight, which was estimated to take two hours and six minutes. The aircraft was refuelled and taxied to Apron V at the Winnipeg International Airport, where it was loaded with cargo. After loading was complete, the pilot obtained an instrument flight rules (IFR)[2] clearance for the flight to Thunder Bay, taxied to Runway 36, received take-off clearance, and departed.

The aircraft climbed on runway heading for about one minute to an altitude of 1300 feet above sea level (asl), 500 feet above ground level (agl). The flight was cleared to 9000 feet asl direct to Thunder Bay, and the pilot turned on course. The aircraft continued to climb, reaching a maximum altitude of 2400 feet asl about 2.5 minutes after take-off. The aircraft then started a gradual descent averaging about 400 feet per minute (fpm) until it descended below radar coverage. The accident occurred during hours of darkness at 0543. The Winnipeg Fire Paramedic Service were notified and responded from a nearby station.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	1	–	–	1
Serious	–	–	–	–
Minor/None	–	–	–	–
Total	1	–	–	1

1.3 Damage to Aircraft

The aircraft was destroyed by the impact forces and the post-impact fire.

1.4 Other Damage

The occurrence impact and post-impact fire damaged several sections of the north and south main-line railway tracks at Mile 1.1 of the Canadian National (CN) Rivers Subdivision near the intersection of Donald Street and Corydon Avenue in Winnipeg.

1 All times are central daylight time (Coordinated Universal Time [UTC] minus five hours).

2 See Glossary at Appendix H for all abbreviations and acronyms.

1.5 *Personnel Information*

	Pilot-in-Command
Pilot Licence	ATPL
Medical Expiry Date	01 December 2005
Total Flying Hours	4570
Hours on Type	1500
Hours Last 90 Days	57
Hours on Type Last 90 Days	57
Hours on Duty Prior to Occurrence	2
Hours Off Duty Prior to Work Period	12

The pilot began work with Morningstar Air Express Inc. (Morningstar) on the Cessna 208 aircraft type in November 2000. The pilot proficiency checks (PPCs) and instrument rating renewals were reviewed. The PPC in February 2005 included a satisfactory rating for icing encounter. The pilot's last flight simulator training was successfully completed in January 2005. The last recurrent ground training was successfully completed in April 2005 and covered the following: dangerous goods, surface contamination, ground and airborne icing, emergency procedures, survival, cockpit resource management, controlled flight into terrain, workplace hazardous materials, minimum equipment, and airline security training segments.

The pilot held an airline transport pilot licence (ATPL) issued 09 April 1999 with a Group 3 instrument rating and validated by a Category I medical certificate. The pilot's logbook was not recovered. However, an examination of Transport Canada (TC) files and the operator's records indicated that the pilot had about 1500 hours on the Cessna 208 aircraft type and had a total of about 4570 flying hours, including 19 hours flown in the 30 days before the accident.

At the time of the accident, the pilot was based in Moncton, New Brunswick, and had been temporarily based in Winnipeg to replace another pilot who was on vacation. The pilot travelled from Moncton to Winnipeg on 02 October 2005 and flew 4.8 hours on October 3 from Winnipeg to Thunder Bay and return. The pilot was on reserve duty from October 4 until 1400 on October 5.

Records indicate that the pilot checked into a local hotel and last entered the room at 1310 on 05 October 2005. The pilot made several telephone calls; the last one at 1937. The pilot reported for duty at the Winnipeg International Airport at about 0315 on October 6 and was alert and in good spirits.

1.6 Aircraft Information

Manufacturer	Cessna Aircraft Company
Type and Model	208B Caravan (with optional cargo pod)
Year of Manufacture	1996
Serial Number	208B0542
Certificate of Airworthiness	issued 02 December 2003
Total Airframe Time	6724 hours
Engine Type (number of)	Pratt & Whitney Canada PT6A-114A (1)
Propeller Type (number of)	McCauley Accessory Division 3GFR34C703/106GA-0 (1)
Maximum Allowable Take-off Weight	8750 pounds (8550 pounds in icing conditions)
Recommended Fuel Type(s)	Jet A, Jet A-1, Jet B
Fuel Type Used	Jet A-1

1.6.1 General

An examination of the aircraft's maintenance records indicates that it was maintained in accordance with the approved procedures in the company maintenance control manual. The aircraft underwent a Phase 12 inspection on 06 September 2005, 94 flying hours before the accident. There were no reported outstanding unserviceabilities.

1.6.2 Aircraft Loading

Under the pilot self-dispatch system approved for the operator, the pilot was responsible for completing weight and balance computations before each flight and, where practical, leaving a copy at the point of departure.[3] Although no copy of the weight and balance form was found at the point of departure, a damaged and partially completed weight and balance form for the flight was recovered at the accident site. This weight and balance form did not include computations of the aircraft's take-off weight or centre of gravity (CG). The pilot had made entries in the weight and balance blocks for the aircraft basic weight (4842 pounds, index 437[4]), take-off fuel (1600 pounds, index 39), and pilot weight (120 pounds, index 985). The figures 7030, 4842, and 2188 were entered in the remarks block in a column with no arithmetic notation.

3 The investigation determined that company Caravan pilots based in Winnipeg did not normally leave a copy of the weight and balance form at the point of departure.

4 Index values simplify the calculation of centre of gravity.

Technical records for C-FEXS showed the aircraft basic weight as 4844 pounds with an index of 436.83. The investigation revealed an error in the recorded aircraft basic weight computation. During the replacement of a lead acid battery with a lighter nickel-cadmium battery, the resulting weight difference was added to the basic aircraft weight rather than being subtracted. The correct aircraft basic weight was 4837 pounds with an index of 438.18.

The aircraft had 1225 pounds of fuel remaining at shutdown following the previous day's flight from Thunder Bay to Winnipeg. Before the accident flight, 242 litres of Jet A-1 fuel were added, which increased the aircraft's ramp fuel weight to 1677 pounds. The aircraft was run up and taxied from Apron II to Apron V for loading, and then taxied to Runway 36 for take-off. It was estimated that the aircraft burned about 70 pounds of fuel during ground operations, and the estimated fuel weight at take-off was about 1607 pounds.

Impact and post-impact fire damage precluded weighing the cargo during the investigation. The cargo manifest given to the pilot indicated a cargo weight of 2288 pounds. This weight was obtained by adding the weight of cargo originating in Winnipeg (570 pounds) to the weight of cargo originating in Toronto, Ontario (1718 pounds). The Winnipeg cargo weight had been calculated by subtracting the tare weight of the container holding the cargo from the gross weight of the container and cargo. However, an incorrect tare weight of 300 pounds was used rather than the actual tare weight of 308 pounds stated on the side of the container; therefore, the Winnipeg cargo weight was 562 pounds.

The Toronto cargo weight was also calculated by subtracting the container's tare weight from the gross weight. However, during the investigation, the freight company noted that the 674-pound tare weight marked on the side of this container was incorrect. In addition, an arithmetic error was made when the tare weight was subtracted from the gross weight. When weighed, the container actually weighed 470 pounds. Therefore, the correct Toronto cargo weight was 1912 pounds, making the total cargo weight 2474 pounds.

The maximum take-off weight for the Caravan is 8750 pounds, and the maximum weight for flight into known icing conditions with the cargo pod installed is 8550 pounds. On the occurrence flight, using the corrected weight of the aircraft, fuel, and cargo, the calculated take-off weight was 9038 pounds, 288 pounds greater than the maximum take-off weight and 488 pounds greater than the maximum weight for flight into known icing conditions.

The Caravan cabin is a single, open compartment behind the cockpit seats, with a cargo barrier and barrier nets separating the cabin from the cockpit. The cabin compartment is divided into six zones, with Zone 1 at the forward end of the cabin and Zone 6 at the aft end. Each zone has a maximum load weight that varies depending on whether the cargo in each zone is secured by tie-downs or unsecured using partitions. If the cargo is unsecured, the maximum zone weight is based on a maximum cargo density of 7.9 pounds per cubic foot multiplied by the zone volume. The aircraft was also equipped with an external belly cargo pod, which was divided into four compartments, with Compartment A at the forward end of the pod and Compartment D at the aft end. Each pod compartment has a maximum load weight.

The air operator used a bulk loading method, and loading personnel were advised to place heavier articles toward the forward part of the cabin. The cargo was confined in the aircraft cabin and cargo pod, but was not secured by tie-downs. The total weight of the cargo was known, but the actual weight of cargo in each zone was unknown and was estimated. Shortly before departure, the aircraft was loaded with the cargo being placed in the cabin from Zone 1 through Zone 5. A net was placed between the cargo in Zone 5 and Zone 6, which was left empty. Several pieces of cargo estimated to weigh 200 pounds could not be loaded forward of this net and were loaded into compartments B and C in the cargo pod.

The Cessna 208B aircraft flight manual (AFM) states that "precautions must be taken to protect the forward and aft CG limits . . . A means of protecting the CG aft limit is provided by supplying an aft CG location warning area between 38.33% mean aerodynamic chord (MAC) and the maximum allowable aft CG of 40.33% MAC. This warning area is indicated by shading on the CG moment envelope and CG limits. **This shaded area should be used only if accurate CG determination can be obtained**." (Emphasis in the AFM)

The investigation could not precisely determine the aircraft's CG because the cargo in each zone was not weighed separately. However, calculations determined that, when the aircraft was loaded within the weight limitations for each zone or compartment, the CG was likely within the 36.2 to 40.1 per cent MAC range. The portion of this range from 38.33 to 40.1 per cent MAC would be within the shaded warning area of an extrapolated CG limit chart (see Appendix A – Centre of Gravity Calculations).

Bulk loading trials were conducted during the investigation. The trials determined that, unless the cargo in each zone was weighed, it was possible for cargo density to inadvertently exceed 7.9 pounds per cubic foot, resulting in the zone weight exceeding the zone maximum weight limit for cargo unsecured by tie-downs.

1.7 Meteorological Information

1.7.1 General

On the day of the occurrence, southern Manitoba was under the influence of a strong low pressure system and occluded frontal wave situated over Lake Superior at 0400. The system had moved eastward through the Winnipeg area the day before the occurrence and brought with it the first significant snowfall of the season. In the wake of the system, there were strong winds, broken-to-overcast stratocumulus clouds, and light snow over southern Manitoba. Instrument meteorological conditions (IMC) prevailed over southern Manitoba, northwestern Ontario, and northern Minnesota.

1.7.2 Forecast Weather

A Winnipeg aerodrome forecast (TAF) was issued at 0038 on the day of the accident and subsequently amended at 0344 and 0504 to reflect changing visibilities and ceilings. The TAF amendment issued at 0504, for the period from 0500 to 0900, was as follows: winds 360° at 15 knots gusting to 25 knots, visibility greater than 6 statute miles (sm) with light snow, scattered clouds at 800 feet agl, broken clouds ceiling at 3000 feet agl, and overcast clouds at 7000 feet agl, with temporary conditions of visibility 3 sm with light snow and broken clouds ceiling at 600 feet.

Graphic area forecasts (GFAs) are issued four times daily with a coverage period of 12 hours. Each issue is a collection of six charts: two charts valid at the beginning of the forecast period, two charts valid 6 hours into the forecast period, and the final two charts valid 12 hours into the forecast period. Two charts are issued for each specified time: one chart depicts clouds and weather conditions, and the other chart depicts icing, turbulence, and freezing level conditions. Amendments to area forecasts are issued as AIRMETs. GFAs valid for 0100 and 0700 were issued for the Prairies region, covering the Winnipeg area, at 0031 and 0041, respectively (see Appendix B – Graphic Area Forecasts for the Route of Flight). No AIRMET amendments were made to these GFAs.

The 0100 clouds and weather chart depicted a low pressure system with a central pressure of 1009 millibars over northwestern Minnesota. In southeastern Manitoba, including the Winnipeg area, overcast clouds were expected with a ceiling at 1500 feet asl and cloud layers topped at 22 000 feet asl, visibility was expected to range from 1 to 3 sm in light-to-moderate snow, with local visibility ½ sm in moderate snow and blowing snow. Extensive areas of ceilings from 500 to 1000 feet agl, with local ceilings of 200 feet agl, were expected. Over extreme southeastern Manitoba, isolated ice pellets were expected.

The 0100 icing and turbulence chart depicted a low pressure system over northern Minnesota, with a low-level jet stream with northeasterly winds of 60 knots to the north of the low over Manitoba, immediately in the vicinity of the accident site, with moderate-to-severe mechanical turbulence from the surface to 4000 feet agl depicted. The chart depicted the freezing level at the surface in the vicinity of Winnipeg, sloping to 2500 feet asl to the southeast. The chart depicted moderate mixed icing from the freezing level to 20 000 feet asl over most of southern Manitoba, including the Winnipeg area. Over the extreme southeastern corner of Manitoba, the chart depicted local severe mixed icing from the freezing level to 18 000 feet asl.

The 0700 clouds and weather chart depicted the low pressure system having moved northeastward into Ontario. In southeastern Manitoba, including the Winnipeg area, overcast clouds were expected, with a ceiling at 1500 feet asl and cloud layers topped at 18 000 feet asl, and visibility was expected to range from 1 to 3 sm in light snow. Extensive areas of ceilings from 400 to 1000 feet agl were expected, with scattered convective clouds topped at 18 000 feet asl. Local visibility of ¾ sm in light snow and blowing snow was expected. In southwestern Manitoba, just to the west of Winnipeg, visual meteorological conditions were expected.

The 0700 icing and turbulence chart depicted moderate mechanical turbulence from the surface to 3000 feet agl over southeastern Manitoba, including the Winnipeg area. The chart depicted moderate mixed icing in cloud from the freezing level to 16 000 feet asl over southeastern Manitoba, with the western edge of the forecast icing just to the east of Winnipeg.

Significant meteorological messages (SIGMETs) are intended to provide short-term warnings of certain potentially hazardous weather phenomena, one of which is icing. There were no SIGMETs issued for the Winnipeg area on the day of the accident.

1.7.3 *Observed Weather*

A special weather observation (SPECI) taken at Winnipeg at 0531 was as follows: winds 360° at 15 gusting to 20 knots, visibility 4 sm in light snow and mist, broken cloud ceiling at 1000 feet agl, overcast cloud at 5300 feet agl. The 0600 aviation routine weather report (METAR) was as follows: winds 360° at 15 knots, visibility 6 sm in light snow and mist, scattered cloud at 700 feet agl, broken cloud at 1700 feet agl, overcast cloud at 5500 feet agl, temperature -1°C, dew point -1°C, altimeter 30.26 inches of mercury (in Hg), remarks cloud stratus fractus 4, stratocumulus 2, stratocumulus 2. The 0700 METAR was as follows: winds 360° at 13 knots, visibility 15 sm in light snow, broken cloud at 800 feet agl, broken cloud at 4000 feet agl, temperature -1°C, dew point 1°C, altimeter 30.27 in Hg, remarks cloud stratus fractus 5, stratocumulus 2.

An aircraft that departed Winnipeg two minutes before the accident aircraft was equipped with a flight data recorder (FDR) that was analysed by the TSB Engineering Laboratory. The FDR analysis revealed that the temperature aloft at 1800 feet asl was -2°C, and -3°C at 2400 feet asl.

1.7.4 *Icing Forecasting*

The International Civil Aviation Organization defines icing intensity in terms of the effect of ice accretion on aircraft. The following definitions are taken from the Environment Canada publication *Manual of Standards and Procedures for Aviation Weather Forecasts* (MANAIR):

- Light icing — The rate of ice accretion is such that flying for prolonged periods (over one hour) without using de-icing equipment may create a problem. Occasional use of de-icing or anti-icing equipment removes or prevents ice accretion. If de-icing or anti-icing equipment is used, no problem occurs.

- Moderate icing — The rate of ice accretion is such that even short encounters become potentially hazardous. De-icing or anti-icing equipment must be used or a diversion is necessary.

- Severe icing — The rate of ice accretion is such that de-icing or anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary.

Canadian weather forecasters prepare icing intensity forecasts of nil, trace, light, moderate, or severe based on a subjective estimate of how the conditions will have an impact on aircraft operations, as described in the above definitions. The National Oceanic & Atmospheric Administration (NOAA) uses a program, Current Icing Potential (CIP)/Forecast Icing Potential (FIP), which can forecast trace icing over southern Canada. Some of the factors considered by the forecaster are temperature, convective activity, cloud liquid water content, and water droplet size. Information from upper air soundings, weather radar, satellite imagery, surface weather observations, pilot reports, and computer model output is evaluated to produce icing forecasts.

Different aircraft types have greatly varied tolerances for operation in icing conditions. The effects on some aircraft types could be minimal, while other aircraft types operating in the same icing conditions could be significantly affected. The differences in icing tolerances between different aircraft types result from varying aerofoil shapes, aircraft power, drag, speed, operating altitude, and other considerations. Aircraft capable of operating at a relatively higher speed can reduce or avoid ice accretion in the critical temperature range just below 0°C, which prevailed in the Winnipeg area at the time of the accident, by operating at speeds under which compression and friction increase aircraft skin temperatures to above freezing. The Cessna 208 aircraft type operates at relatively lower airspeeds than most other turbopropeller aircraft, such that the effects of friction and compression are reduced. Aircraft type is not considered by weather forecasters when preparing an icing forecast.

The most significant amounts of aircraft ice accretion are usually found at temperatures just below freezing; icing potential decreases at lower temperatures.

1.7.5 Pilot Reports

A review of air traffic control (ATC) records indicated that several aircraft operated in and out of the Winnipeg International Airport at the time of the accident. No other incidents or control difficulties were reported. A review of NAV CANADA records indicated that five pilot reports (PIREPs) were received by NAV CANADA within one hour after the accident. Aircraft types ranged from light (Piper PA-31 Navajo) to large (Boeing 727). The reports indicated that pilots were encountering nil-to-light icing with cloud tops ranging from 5000 to 6000 feet asl. A Beechcraft Baron departed Runway 36 at Winnipeg at 0615 and encountered light icing conditions on the climb and en route to Fort Frances, Ontario. All of the PIREP aircraft had cantilever wings without wing struts, had retractable landing gear, operated without cargo pods, and flew at higher airspeeds than the Cessna 208 aircraft type.

1.7.6 Aftercast

Several aftercasts were requested. These reviewed the available weather data retrospectively to determine the weather conditions that prevailed at the time of the occurrence. A weather analysis conducted by Environment Canada after the accident indicated that the only significant turbulence would have been found in the lower levels and would have been light-to-moderate mechanical. Satellite imagery and surface weather data indicated extensive broken-to-overcast stratocumulus clouds over the area. This convectively unstable moist layer between 2000 and 6000 feet asl, with air temperatures in the range of -3°C to -10°C, was conducive to icing. A weather study was prepared by the National Transportation Safety Board (NTSB) for its accredited representative to the TSB investigation. That weather analysis concluded that, at 0500, there was a large air mass of icing conditions over Winnipeg and eastward with more than a 70 per cent chance of producing airframe icing. It was estimated that there was a low likelihood of supercooled water droplets[5] in the air mass over Winnipeg and in the flight route to Thunder Bay.

1.7.7 Pilot's Weather Briefing

Morningstar and NAV CANADA had an agreement for the Winnipeg Flight Information Centre (FIC) to transmit a weather briefing package by fax on Monday through Friday to the fixed-base operator (FBO) used by Morningstar pilots. The weather briefing package was to consist of two portions. One portion was text containing weather observations (METARs), TAFs, NOTAMs, and upper wind information for the route from Winnipeg to Thunder Bay. The second portion was graphic containing GFAs for the Prairies region. The investigation determined that the agreement had been informally amended at some point and, consequently, the packages being faxed to the FBO on Tuesday through Friday did not include the graphic portion.

On the day of the occurrence, the weather briefing package was faxed to the FBO at 0230. Only text information was faxed. This was the text weather received by the pilot:

- 0200 METARs for Winnipeg and airports en route to Thunder Bay
- TAFs for Winnipeg and airports en route to Thunder Bay
- NOTAMs for Winnipeg and airports en route to Thunder Bay
- Upper winds for Winnipeg and points en route to Thunder Bay

At 0410, the pilot phoned the FIC for a briefing on icing conditions and indicated that the GFA charts had not been faxed. The pilot did not mention the route of flight or aircraft type, and the briefer did not request this information. The briefing included information from the turbulence and icing charts valid for Winnipeg at 0100 and 0700, including the forecast icing for the Winnipeg area and eastern Manitoba.

The pilot received Winnipeg automatic terminal information service (ATIS) India before requesting IFR clearance at 0530. ATIS India provided the 0500 METAR as follows: wind 350° at 16 knots, visibility 3 sm with light snow and mist, ceiling 700 feet agl broken, 1600 feet agl broken, 6200 feet agl overcast, temperature 0°C, dew point 0°C, altimeter 30.24 in Hg. ATIS India also indicated that all runways were 100 per cent bare and wet.

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5 The cloud droplet size is important in determining icing severity, because the higher the liquid water content of a cloud and the larger the size of its droplets, the more likely these droplets are to collide with and, therefore, freeze to the hard surface of a plane. Small cloud droplets—less than 30 microns (30 millionths of a metre) in diameter—are less likely to collide with an aircraft surface because they are lighter and tend to follow the air flow around the plane. Larger drops, such as freezing drizzle (100 to 500 microns) or freezing rain (500 to 3000 microns), are more likely to collide because of their greater momentum. Reference: Environment Canada, "Icing Research Making Skies Safer," in *Science and the Environment Bulletin*, Issue 16, January/February 2000.

1.8 Aids to Navigation

A review of NAV CANADA status information for the time of the occurrence indicated that all relevant navigational aids were operational with no active alarms.

On the date of the occurrence, NAV CANADA radar coverage extended over the Winnipeg International Airport and the entire flight path of the occurrence aircraft. The floor of radar coverage was about 700 feet agl in the area of the accident site.

1.9 Communications

The pilot's communications with Winnipeg ground control, clearance delivery, tower, and departure frequencies were reviewed, and no equipment malfunctions were noted. The pilot made five radio transmissions after take-off:

- 0537:52 — the pilot called departure after take-off as requested by Winnipeg tower;
- 0538:06 — the pilot called departure acknowledging clearance to 9000 feet asl, on a direct track to Thunder Bay;
- 0541:07 — the pilot called departure requesting an immediate return to the airport (departure asked that the message be repeated);
- 0541:15 — the pilot repeated the request for an immediate return to the airport due to aircraft icing (departure instructed MAL8060 to turn right to 250° and to maintain 2500 feet asl if possible); and
- 0541:29 — the pilot made a partial transmission acknowledging the clearance; however, the transmission was cut off.

1.10 Aerodrome Information

The Winnipeg International Airport is operated by the Winnipeg Airports Authority Inc. At the time of the occurrence, the aerodrome had three runways: 13/31, 18/36 and 07/25. All of these runways were hard-surfaced and were suitable for Cessna 208 operations. The aerodrome elevation is 783 feet asl. The aerodrome has a central de-icing facility, which includes a lighted ramp with a fluid recovery system. At the de-icing facility, aircraft operators are responsible for applying de-icing fluids to their aircraft.

1.11 Flight Recorders

The occurrence aircraft was not equipped with an FDR or a cockpit voice recorder (CVR), nor were they required by regulation. The aircraft was equipped with a power analyzer recorder (PAR), which records certain engine and aircraft data parameters. The data are recorded on memory chips on a circuit board, and the memory is maintained by a small battery in the unit. The PAR was severely damaged, but was recovered and sent to the TSB Engineering

Laboratory. Examination of the PAR unit revealed that the battery had become disconnected from the circuit board. The damaged portions of the PAR were replaced to access the memory chips, and power was restored, but the data recorded in the PAR had been lost.

1.12 Wreckage and Impact Information

The aircraft struck the ground in an inverted steep nose-down, left-wing-low attitude on a heading of 255° magnetic. The wings struck and separated from the fuselage, and spanned both the north and south CN railroad tracks on a 45° angle to the tracks. The nose of the aircraft embedded into the heavy stone rail bed. The tail and cargo pod and main landing gear sheared off and came to rest approximately 20 feet forward of the main impact crater. Lighter cargo and paperwork were spread forward of the wreckage and up against a fence approximately 30 feet from the north track. The forward fuselage and cockpit structure was compressed to less than half of its normal length. The three propeller blades had broken free from the hub and all exhibited leading edge damage with a twist to low pitch, indicative of being powered at impact.

The flight control system was examined to the extent possible. Continuity was confirmed in the control system cabling and push-pull rods, with all fractures determined to be a result of overload. An examination of the flap system indicated that the flaps were in the up (retracted) position at impact. The captured position of the engine inertial separator doors indicated that the doors were likely in the normal position at impact. There was no ice adhering to any portions of the wreckage; however, any ice would have been removed by the force of the impact, the ensuing post-crash fire, and the resulting fire-fighting efforts.

The engine was taken to the Pratt & Whitney manufacturing facilities in Saint-Hubert, Quebec, for examination under TSB supervision. Internal engine damage indicated that the engine was producing significant power at impact and all engine damage was the result of impact forces. A review of the engine trend monitoring records, regularly carried out by the operator, revealed no indication of degraded engine performance before the occurrence.

The significant power signatures observed during the engine teardown were confirmed by the engine instrument analysis conducted at the TSB Engineering Laboratory facilities. The result of the instrument examination indicated that the engine was operating at full power at the time of impact. Of note were the gas generator speed (Ng) of over 100 per cent and the inter-turbine temperature (ITT) reading of approximately 600°C. Had the engine compressor inlet begun to ice over and restrict airflow, the Ng reading would have been substantially lower and the ITT reading substantially higher.

The Cessna 208 is equipped with four electrically activated de-ice valves that control the pneumatic boots on the landing gear struts and cargo pod, the horizontal and vertical stabilizers, the inboard wing, and the outboard wing and struts. The four de-ice valves were examined by the TSB Engineering Laboratory. The internal components of the inboard wing boot de-ice valve were found displaced from their normal operating position and differed from the positions of those of the remaining three valves. This internal displacement in the valve could imply that the boots were on the inboard wing inflation cycle at impact. However, a definitive conclusion could not be reached due to the lack of internal impact markings. No pre-existing discrepancies that could have prevented normal operation were noted.

The aircraft's annunciator panel was sent to the TSB Engineering Laboratory to see if any of the panel's light bulbs were illuminated at impact. Only two intact lamps were recovered from the panel. Both belonged to the "Voltage Low" indicator, which was determined to be off at impact.

1.13 Medical and Pathological Information

The pilot's medical information was reviewed and no anomalies were noted. The autopsy results indicated death by blunt trauma. Toxicology results were negative for alcohol and drugs.

1.14 Fire

After the aircraft struck the ground, a post-crash fire consumed nearly 50 per cent of the aircraft wreckage and cargo. Winnipeg's Fire Paramedic Service responded to the scene and extinguished the fire.

1.15 Survival Aspects

The impact forces exceeded the design limits for the aircraft's seats and restraint systems, and the aircraft's cabin space was compromised by the crushing of the fuselage. The accident was not survivable.

1.16 Tests and Research

Investigators travelled to Memphis, Tennessee, United States, and conducted a number of flights in an approved Level D flight simulator at the flight training academy used by the operator for recurrent pilot training. Level D simulators are certified to replicate aircraft performance to a sufficient degree that they may be used to perform PPCs. However, an exact match of aircraft performance under all conditions is not assured.

The simulator was set up to depart from Winnipeg, with the flights incorporating various combinations of aircraft weight and atmospheric conditions. For flight scenarios with a take-off weight of 8809 pounds[6] and moderate icing conditions starting at 1000 feet agl, the simulator could not be successfully flown back to a landing at Winnipeg. For flight scenarios flown at 120 knots, the simulator remained in control, but all landings were off-airport. All of the scenarios that were flown at 105 knots ended with either loss of aircraft control or an off-airport landing.

1.17 Organizational and Management Information

Morningstar is a TC–approved air operator based in Edmonton, Alberta. The company was authorized to carry freight in IFR operations with the Boeing 727 and Cessna 208 aircraft types. The accident aircraft was on a dedicated contract to transport freight between Winnipeg and

[6] The flight scenarios were performed early in the investigation before the more accurate estimate of aircraft take-off weight (9038 pounds) was determined. Therefore, the flight scenarios flown with a weight of 8809 pounds were conservative.

Thunder Bay. Morningstar had an approved program for using Type I de-icing fluid and Type IV anti-icing fluid. The program incorporates hold-over tables, which specify hold-over times of 11 to 18 minutes for Type I fluid and 15 to 60 minutes for Type IV fluid, depending on atmospheric conditions and fluid concentration. The fluids and related application equipment were on hand before the accident flight.

Pilots were encouraged to use the de-icing facilities as required. There was no indication of pressure on the operator's pilots to refrain from using the de-icing or anti-icing fluid to save expense or inconvenience. There was no indication of pressure on the operator's pilots to dispatch into adverse weather conditions or to accept overweight or out-of-CG cargo loads.

1.18 Additional Information

1.18.1 Dangerous Goods

The aircraft was carrying dangerous goods, namely six vials of biological material containing potentially infectious substances. After the initial response by the Winnipeg Fire Paramedic Service, Province of Manitoba personnel removed the material for disposal. The biological material was considered to be relatively low risk, and there was no indication that any of it had been released into the ground or the atmosphere.

1.18.2 Cessna 208 Canadian Type Certification

The Cessna 208 aircraft type is a high-wing monoplane with fixed landing gear and wing struts. The aircraft is certified for single-pilot operations into IMC. Many Cessna 208 aircraft have been fitted with a belly-mounted pod to carry extra cargo volume. The Cessna 208 series aircraft type was issued a Canadian type certificate in 1984, based on its certification by the United States Federal Aviation Administration (FAA). The manufacturer's application for FAA certification contained flight testing results, including flight testing in simulated and actual icing conditions. The aircraft Canadian type certification was issued after a one-day familiarization of a sample aircraft by TC officials. The TC certification process did not incorporate any flight testing or assessment of the aircraft's performance in icing conditions. Since the Cessna 208 aircraft was originally certified, flight tests of several series of Cessna 208 aircraft have been undertaken to assess performance in icing conditions.

The Cessna 208 aircraft type was certified to comply with the ice-protection requirements of Section 23.1419 of the United States *Federal Aviation Regulations* (FARs) when the ice-protection equipment is installed in accordance with the aircraft equipment list. The details of the equipment and procedures for the aircraft's approval for flight into icing conditions are contained in Supplement S1, Revision 7, to the AFM. Supplement S1, Revision 7, effective June 2005, was in effect at the time of the accident. The accident aircraft was equipped with a Cessna 208 ice-protection equipment package. Part of this package includes pneumatic de-icing boots on the wings, wing struts, main landing gear struts, cargo pod nose cap, and the horizontal and vertical stabilizer leading edges. Also included are electrically heated propeller blade anti-icing boots and a detachable electric windshield anti-ice panel.

The ice protection certification allows flight into icing conditions as defined by FAR 25 Appendix C[7] envelopes for continuous maximum and intermittent maximum icing when the aircraft is operated in accordance with the Pilot's Operating Handbook (POH) and the FAA-approved AFM. Supplement S1, Revision 7, provides that "These conditions do not include all icing conditions that may be encountered (e.g. freezing rain, freezing drizzle, mixed conditions, or conditions defined as severe)." Flight into known moderate icing conditions is permitted.

1.18.3 Cessna 208 Operations in Icing Conditions

Supplement S1, Revision 7, to the AFM specifies that a tactile check of the upper wing surface, the horizontal tail leading edge, and the propeller blades is required if the temperature is below 5°C and there is visible moisture present, if the aircraft has been exposed to visible moisture since the previous landing, if the temperature/dew point spread is less than 3°C, if the aircraft has been exposed to in-flight icing, or if there is water on the wing. The tactile check must be performed within five minutes of take-off, except when approved de-icing has been performed and the check is within the hold-over period specified in such procedures.

The pilot performed a tactile check of the wing while the aircraft was being loaded, using a belt-loader to access the upper wing area. It was not determined to what extent the pilot checked the horizontal tail leading edge, pitot-static system, stall warning heaters, or propeller during the tactile check. The results of the tactile check were not recorded, nor were they required to be. The tactile check was completed at 0525, about 12 minutes before take-off. Ground crew did not note any contamination on the aircraft while it was at the loading ramp. It was not determined whether any further tactile inspection of the aircraft was performed after the aircraft departed the loading ramp. The investigation found nothing that indicated that the aircraft departed with ice or snow adhering to its critical surfaces.[8]

Supplement S1, Revision 7, advises pilots that "whenever icing conditions are encountered, immediate action should be taken to leave these conditions before airplane performance is degraded to a point where a climb, which is normally the best action to take, may not be achievable due to the residual ice buildup." Residual ice is any ice remaining on the aircraft's protected surfaces after operating the de-icing boots.

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7 See Appendix C – Icing Parameters

8 In the Transport Canada publication TP 10643 titled *When in Doubt. . . Small and Large Aircraft – Aircraft Critical Surface Contamination Training for Aircrew and Groundcrew*, "critical surface" is defined as ". . . the wings, control surfaces, rotors, propellers, horizontal stabilizers, vertical stabilizers or any other stabilizing surface on an aircraft. . ." The Cessna 208 Pilot's Operating Handbook Supplement S1, Revision 7, specifies the surfaces to be inspected for that aircraft type.

Supplement S1, Revision 7, specifies a minimum speed of 105 KIAS (knots indicated airspeed) during flight into icing conditions with the flaps up. It also directs pilots, if altitude cannot be maintained at 120 KIAS in icing conditions, to immediately request priority handling from ATC to facilitate a route or altitude change to exit the icing conditions. On encountering icing conditions, pilots are required to

- select windshield heat,
- select propeller anti-ice,
- switch on the ice detector light,
- monitor ice build-up until ¼ to ¾ inch of ice accumulates on the wing leading edge, and
- select the boot switch to auto to activate the airframe de-icing boots for each cycle.

Supplement S1, Revision 7, provides that "optimum performance of the de-ice and anti-ice boots is dependant on keeping the boots clean and coated with an ice adhesion depressant such as ICEX II." The operator's records indicated that, on the day before the accident, the windshield anti-ice panel was installed and ICEX II was applied to all boots in accordance with the applicable maintenance manual.

Cessna has produced an information package titled *Caravan Safety Awareness Program*. Information in this package indicates that airspeed may reduce from 165 to 105 knots after repeated operation of the de-icing boots in icing conditions, accompanied by a significant increase in the aircraft's stall speed. As well, the aircraft's ability to sustain a climb is reduced, and the aircraft may not be able to maintain its altitude and may be required to descend.

1.18.4 Aircraft Performance

The aircraft was not equipped with an FDR. Aircraft performance was evaluated by combining ATC radar data that indicated aircraft position, altitude, and groundspeed, with atmospheric information from the FDR of an aircraft that departed Winnipeg two minutes before the accident aircraft. The performance analysis, done by the TSB Engineering Laboratory, yielded performance information, which was plotted graphically indicating altitude and rate of climb (see Appendix D – Altitude versus Rate of Climb/Descent), and altitude, groundspeed, and airspeed (see Appendix E – Altitude versus Groundspeed/Airspeed). It should be noted that, while the overall results are considered to be relatively accurate, the results depend on the accuracy of ATC radar data. As well, the radar sampling rate produces individual data points with "roughness"(variability) because the information is not updated continuously.

The performance analysis revealed that the aircraft's airspeed varied during the flight; the aircraft accelerated to about 100 knots while climbing out shortly after take-off, then decreased to as low as 73 knots, then increased again to 100 knots before reducing again. The last data points indicated airspeeds in the mid 90-knot range. The AFM indicates that the best rate of climb speed at 8750 pounds with flaps at 20 is 90 knots; the flaps-up best rate airspeed is 104 knots. The aircraft's stall speed in level flight with flaps at 20 is 63 knots; the flaps-up stall speed is 78 knots. As with any aircraft, the Cessna 208's level-flight stall speed increases with bank angle in a turn.

The aircraft's rate of climb increased after take-off to about 1000 fpm, and then settled in the range of 600 to 850 fpm until about two minutes after take-off. The rate then declined steadily to a descent of about 700 fpm, when the data ends. The AFM indicates that the aircraft's maximum rate of climb for 0°C at 8750 pounds ranges from 815 fpm with flaps at 20° to 940 fpm with flaps up.

Supplement S1, Revision 7, recommended a climb airspeed of 120 knots in icing conditions to reduce ice build-up aft of the de-icing boots. However, a climb at Vy (best rate of climb airspeed) was recommended, if required to climb above icing conditions.

An optional low airspeed advisory system, which was not incorporated in the accident aircraft, illuminates an annunciator panel advisory light when pitot heat is on, flaps are 0 degrees, and airspeed is below 105 knots. Supplement S1, Revision 7, indicated that the low airspeed advisory system does not limit airspeeds for the take-off or approach phases of flight.

Supplement S1, Revision 7, states that ice accumulations on the airframe may result in a stall speed increase of 20 knots or more and a decrease in climb rate of 500 fpm or more. With significant ice accretions, the aircraft's stall warning margin may decrease to the point that the aural stall warning may be concurrent with the pre-stall airframe buffet. Supplement S1, Revision 7, warns: "Do not cycle the boots during landing (below approximately 500 ft agl) because boot inflation may increase stall speed by as much as 10 knots."

The engine power limits for take-off, climb, and cruise are 1865 foot-pounds torque, 675 shaft horsepower. The aircraft's flap setting during the flight could not be determined with certainty. Normal company practice was to depart with 20 degrees of flaps and retract the flaps at about 400 feet agl. The flaps were in the retracted position at impact.

Aircraft loss of control can occur in several ways. Aircraft can experience wing stalls, which may progress into spins. Aircraft with significant tailplane icing can experience tailplane stalls, which can lead to steep nose-down descents. There was insufficient information to determine the exact mode of loss of control for MAL8060.

1.18.5 Other Occurrences

On the day before the accident, C-FEXS was flown from Thunder Bay to Winnipeg by a different pilot. This flight departed from Thunder Bay at 1600 and arrived at Winnipeg at 1805. En route to Winnipeg at 6000 feet, the aircraft encountered moderate icing conditions that degraded its performance. The pilot was unable to maintain altitude and descended to exit icing conditions, first to 4000 feet asl, and then to 3000 feet asl, where the aircraft could maintain altitude. During the final approach to Winnipeg, the aircraft descended into warmer air and the ice shed from the aircraft. The GFA for Manitoba at the time of this flight depicted moderate mixed icing from the freezing level to 20 000 feet asl, and the GFA for Ontario depicted moderate mixed icing from the freezing level to 19 000 feet asl. The GFAs depicted the freezing level above 12 500 feet asl at Thunder Bay, decreasing to 2500 feet asl in eastern Manitoba.

TSB investigators reviewed 19 other occurrences worldwide from 1990 to 2006 involving Cessna 208A and 208B aircraft operating in airborne icing conditions. These occurrences resulted in 31 fatalities and 4 serious injuries. In 12 occurrences, the aircraft were destroyed, in 4, the aircraft sustained substantial damage, in 1, there was minor damage, and in the other 2 occurrences, there was no damage. In all, 13 occurrences resulted in total loss of aircraft control, in 4 occurrences, the pilot maintained aircraft control but was unable to maintain altitude, and in 2 occurrences, information is not available. Summaries of these occurrences are contained in Appendix F – Other Occurrences.

2.0 Analysis

2.1 Weather

The icing conditions over Winnipeg were still forecast as moderate at the time of the accident, 0543. Aircraft that operated in the Winnipeg area were encountering in-flight icing conditions at the time of the accident and as late as 0615, although the forecast called for icing conditions to have moved to the east of Winnipeg before the end of the forecast period, 0700. Lower-than-forecast cloud ceilings persisted as late as 0700, indicating that the weather system over the Winnipeg area was moving somewhat more slowly than forecast. As a result of the slower weather system movement, icing conditions prevailed in the Winnipeg area longer than anticipated.

Icing forecasts are prepared to inform pilots of expected aircraft icing based on the forecast atmospheric conditions. However, the intensity descriptions ("nil," "trace," "light," "moderate," etc.) are not quantitative; they are an opinion about the effects of the icing on a generic aircraft. Even though different aircraft may be certified for flight into icing conditions according to the same criteria, different aircraft types have widely differing capabilities to maintain flight into icing conditions, due to differences in aerofoil shape, power, drag, speed, altitude, and other considerations. Therefore, the generic icing forecast may not be effective in predicting the effects of icing conditions on particular aircraft. By contrast, other atmospheric information, such as forecast winds aloft for example, is disseminated in quantitative terms. This allows pilots to combine the data with their particular aircraft performance information for a more accurate result.

2.2 Pre-Flight Preparation

The pilot did not receive the GFAs with the faxed weather and, therefore, did not view the pictorial display of the icing forecast. The weather system over Winnipeg and the flight route to Thunder Bay was moving eastward more slowly than forecast and, therefore, the icing conditions lingered in the Winnipeg area and eastward longer than forecast. Because the telephone briefing dealt mostly with conditions in the Winnipeg area, and the pilot was unable to view the GFA charts, it is possible that the pilot's understanding of the icing situation was less than complete, especially regarding the eastern portion of the flight route. However, the telephone briefing described the forecast moderate icing conditions over Winnipeg and eastern Manitoba, and those conditions prevailed throughout the flight route. Therefore, it was unlikely that the lack of the GFAs contributed to the pilot's decision to dispatch the flight or the subsequent encounter with icing conditions in the Winnipeg area.

2.3 Aircraft Ground Icing

Because the aircraft was parked in a heated hangar overnight, it was free of snow and ice contamination when it was pulled out at 0410. During the run-up, the taxi to Apron V, and loading, the aircraft was subject to light snow and 15-knot winds. The snow, if it had accumulated on the aircraft's critical surfaces, could have contaminated them and could have led to control issues and a loss of aircraft performance. However, the rate of snowfall was light, a 15-knot wind was blowing, and no pre–take-off contamination on the accident aircraft was observed. Therefore, it is unlikely that the aircraft's critical surfaces were contaminated at the time of the pilot's tactile inspection.

The pilot performed a tactile check of the aircraft's wing before take-off; it could not be determined to what extent the pilot checked the leading edge of the horizontal tail, the pitot-static system, stall warning heaters, or the propeller blades as required by the AFM. However, it is likely that a check of the wing would have revealed contamination from falling snow, if it had been present. The timing of the check, completed 12 minutes before take-off, exceeded the time specified for tactile inspections in the AFM. The environmental conditions were relatively uniform after the aircraft was pulled from the hangar, and the aircraft had been outside for more than one hour at the time of the tactile inspection. If contamination had not accumulated before the tactile check, it is unlikely that critical surface contamination would have accumulated between the time of the tactile inspection and take-off. Because de-icing was readily available and pilots were encouraged to use it when necessary, it is unlikely that the aircraft would have departed with contaminated critical surfaces had such contamination been noted during the tactile check.

2.4 Aircraft Loading

The pilot made some initial calculations in the remarks block of the weight and balance form, listing three numbers in a column (7030, 4842, 2188) without elaboration. When the pilot's calculated take-off fuel of 1600 pounds and the pilot's weight are subtracted from the aircraft's maximum take-off weight of 8750 pounds, the remainder is 7030 pounds. When the recorded basic aircraft weight of 4842 pounds is subtracted from 7030 pounds, the remainder is 2188 pounds, indicating the maximum weight of the cargo so as not to exceed the maximum take-off weight of 8750 pounds.

The investigation did not determine why the pilot accepted the cargo manifest weight of 2288 pounds when the calculations showed a maximum weight of 2188 pounds to remain within the 8750-pound maximum take-off weight. On paper, this would put the aircraft 100 pounds overweight when in fact it was 288 pounds overweight, 488 pounds overweight for flight into icing conditions.

The aircraft's CG could not be accurately determined, and may have been in the extrapolated shaded warning area on the CG limit chart. Although the investigation determined that the CG was likely forward of the maximum allowable aft CG of 40.33 per cent MAC, the uncertainty caused by bulk loading increased the risk that the CG could have exceeded the maximum allowable aft CG.

The use of cargo containers to hold cargo temporarily to facilitate bulk loading introduces additional risks. There is the risk that the container's tare weight is noted incorrectly, as it was for the Winnipeg container in this occurrence. It is also possible that the container's weight has changed over time because of additions or removals of doors, nets, pallets, or tie-down straps, as it did with the Toronto container in this occurrence. Risk also increases with the additional calculations required to determine the net cargo weight.

2.5 Aircraft Performance

Although the engine inertial separator doors were likely in the normal position at impact, the fact that the engine was producing significant power at impact indicates that the position of the doors was not a factor in the occurrence.

The Cessna 208 aircraft type incorporates fixed landing gear, wing struts, and in many instances, a cargo pod. These features increase aerodynamic drag and collect ice in icing conditions. Aircraft capable of operating at a relatively higher speed can reduce or avoid ice accretion in the critical temperature range just below 0°C (which prevailed in the Winnipeg area at the time of the accident) by operating at speeds at which compression and friction increase aircraft skin temperature above freezing.

The Cessna 208 aircraft type operates at relatively lower airspeeds than some other turbopropeller aircraft; speeds at which the effects of friction and compression are reduced. Because of its lower airspeed, higher aerodynamic drag, and increased ice-collecting surface area, the Cessna 208 aircraft type would likely experience more significant performance degradation than the aircraft involved in the PIREPs. Accordingly, PIREPs from other aircraft types and generic icing forecasts may not be sufficient to estimate the effects of icing on the Cessna 208 aircraft type.

It was not determined why the pilot used 8750 pounds as the maximum take-off weight rather than 8550 pounds for operation in icing conditions. It is possible that the pilot believed that the aircraft could depart in non-icing conditions, and subsequently either avoid the forecast icing conditions en route, or burn enough fuel to be below 8550 pounds before entering icing conditions.

The aircraft departed the Winnipeg International Airport about three per cent over its maximum gross weight. Its rate of climb on departure was somewhat less than the rate indicated in the AFM for an aircraft at maximum gross weight. However, turbulence and gusty wind conditions prevailed at Winnipeg at the time of take-off, and these conditions, along with the aircraft's overweight condition, would have degraded performance. It was therefore concluded that the aircraft was mechanically serviceable at take-off, and departed without significant critical surface contamination.

The aircraft's calculated airspeed fluctuated during the flight, as might be expected in the gusty wind conditions and turbulence. Most of the flight was conducted at airspeeds below the 0° flap Vy (best rate of climb airspeed) and below the 0° flap minimum airspeed in icing conditions. It would, however, have been at or above the 20° flap Vy. Although the flaps were retracted at impact, the flap settings used throughout the flight could not be determined. Without information as to the flap settings, the suitability of the airspeeds during the flight cannot be determined. If the aircraft entered icing conditions in cloud with 0° flap, the airspeeds would have been below the minimum airspeed for those conditions. However, if flaps had been extended during the climb, the 105-knot minimum airspeed would not have applied.

Aircraft performance deteriorated progressively after the aircraft climbed through 1000 feet agl. Cloud ceilings were observed at Winnipeg at 700 feet agl, and were forecast at 1000 feet agl. The reduction in aircraft performance began soon after the aircraft entered cloud and was likely the result of the icing conditions, which were forecast to prevail over Winnipeg at that time and were experienced by other crews.

Information gathered from other occurrences and the manufacturer's information indicate that the stall speed of the Cessna 208 aircraft can rise as a result of residual ice. A further increase could be expected in a turn to position the aircraft for a return to the Winnipeg International Airport. An additional increase of 10 knots could be expected during the cycling of the de-icing boots. These increases in stall speed could approach or exceed the airspeeds maintained by the accident aircraft, and the aircraft would depart controlled flight. The stall could have occurred without warning; airframe icing decreases the stall warning margin and the stall warning may be concurrent with the stall.

2.6 Wreckage Examination

The examination of the aircraft wreckage was hampered by the degree of destruction by impact forces, fire, and fire-suppression activities. However, no defects were noted in the aircraft's structure, its controls, or its systems. The engine was developing significant power at impact. No anomalies were noted in the de-icing system, and it had been functioning normally on the previous flight. The windscreen panel had been installed, and ICEX II had been applied to the boots. The communications system was functioning normally and no navigational problems were noted. The maintenance records did not indicate any deficiencies, and the pilot did not mention any deficiencies. It is concluded that, on departure, the aircraft was serviceable in accordance with existing regulations.

2.7 Flight Recorders

The aircraft was not equipped with an FDR or CVR, nor were such recorders required by regulation. Because the PAR was designed for maintenance purposes, it did not incorporate either the range of data parameters or the durability features of certified FDR and CVR equipment. As a result, a significant amount of occurrence and flight information was not available. Although the investigation was able to derive some of this information by other means, much of this information was not available. The scope of the investigation was limited accordingly.

3.0 Conclusions

3.1 Findings as to Causes and Contributing Factors

1. The aircraft departed at a weight exceeding the maximum take-off weight and the maximum weight for operation in icing conditions.

2. After departure from Winnipeg, the aircraft encountered in-flight icing conditions in which the aircraft's performance deteriorated until the aircraft was unable to maintain altitude.

3. During the attempt to return to the Winnipeg International Airport, the pilot lost control of the aircraft, likely with little or no warning, at an altitude from which recovery was not possible.

3.2 Findings as to Risk

1. Aviation weather forecasts incorporate generic icing forecasts that may not accurately predict the effects of icing conditions on particular aircraft. As a result, specific aircraft types may experience more significant detrimental effects from icing than forecasts indicate.

2. Bulk loading prevented determining the cargo weight in each zone, resulting in a risk that the individual zone weight limits could have been exceeded.

3. The aircraft's centre of gravity (CG) could not be accurately determined, and may have been in the extrapolated shaded warning area on the CG limit chart. Although it was determined that the CG was likely forward of the maximum allowable aft CG, bulk loading increased the risk that the CG could have exceeded the maximum allowable aft CG.

4. The incorrect tare weight on the Toronto cargo container presented a risk that other aircraft carrying cargo from that container could have been inadvertently overloaded.

3.3 Other Findings

1. The pilot's weather information package was incomplete and had to be updated by a telephone briefing.

2. The operator's pilots were not pressured to avoid using aircraft de-icing facilities or to depart with aircraft unserviceabilities.

3. The aircraft departed Winnipeg without significant contamination of its critical surfaces.

4. The biological material on board the aircraft was disposed of after the accident, with no indication that any of the material had been released into the ground or the atmosphere.

5. The fact that the aircraft was not equipped with flight data recorder or cockpit voice recorder equipment limited the information available for the occurrence investigation and the scope of the investigation.

4.0 Safety Action

4.1 Action Taken

4.1.1 Transportation Safety Board of Canada

In January 2006, the TSB sent an Aviation Safety Advisory to Morningstar Air Express Inc. (Morningstar) suggesting that it implement a system (perhaps similar to the container system used in its larger aircraft) that would allow determination of accurate cargo weight per zone.

On 31 January 2006, the Board issued two interim recommendations to the Department of Transport.

Although the manufacturer has taken action to provide procedures for operating the Cessna 208 aircraft type in icing conditions, pilots continue to experience difficulty in maintaining control of the aircraft and exiting those conditions as specified in the aircraft flight manual (AFM). Although the aircraft is approved for flight into moderate icing conditions, continuing occurrence experience and the manufacturer's data indicate that the aircraft may not be able to safely operate in those conditions or to safely exit those conditions as specified in the AFM. Therefore, the Board recommended that:

> The Department of Transport take action to restrict the dispatch of Canadian Cessna 208, 208A, and 208B aircraft into forecast icing meteorological conditions exceeding "light," and prohibit the continued operation in these conditions, until the airworthiness of the aircraft to operate in such conditions is demonstrated. (A06-01, issued January 2006)

The manufacturer's data and historical data from reviewed occurrences indicate that the aircraft's stall speed can increase substantially in icing conditions due to residual ice on the aircraft combined with the effects of operating the de-icing equipment. Although the manufacturer has set a minimum operating airspeed in icing conditions, the Board is concerned that the recommended 105 knots is not sufficient to provide an adequate stall warning threshold. Although the Cessna 208 Pilot's Operating Handbook (POH) Supplement S1, Revision 7, dated 27 June 2005, recommends exiting icing conditions when the airspeed falls below 120 knots, it does not specify 120 knots as the minimum airspeed in icing conditions. Therefore, the Board recommended that:

> The Department of Transport require that Canadian Cessna 208 operators maintain a minimum operating airspeed of 120 knots during icing conditions and exit icing conditions as soon as performance degradations prevent the aircraft from maintaining 120 knots. (A06-02, issued January 2006)

Similar recommendations were also issued to the United States Federal Aviation Administration (FAA) on 31 January 2006.

> The Federal Aviation Administration take action to revise the certification of Cessna 208, 208A, and 208B aircraft to prohibit flight into forecast or in actual icing meteorological conditions exceeding "light," until the airworthiness of the aircraft to operate in such conditions is demonstrated. (A06-03, issued January 2006)

> The Federal Aviation Administration require that Cessna 208 operators maintain a minimum operating airspeed of 120 knots during icing conditions and exit icing conditions as soon as performance degradations prevent the aircraft from maintaining 120 knots. (A06-04, issued January 2006)

4.1.2 National Transportation Safety Board

On 17 January 2006, as a result of its participation in the accident investigations being conducted by the Interstate Aviation Commission of Russia and the TSB and its assessment of the circumstances surrounding these accidents, the National Transportation Safety Board issued the following recommendations:

- requiring all operators of Cessna 208 series airplanes to maintain a minimum operating airspeed of 120 knots during flight into icing conditions, even if a descent is required to do so. (A-06-01 – Urgent)

- prohibiting all operators of Cessna 208 series airplanes from conducting flight into any icing conditions determined to be more than light icing. (A-06-02 – Urgent)

- requiring all operators of Cessna 208 series airplanes to disengage the autopilot and fly the airplane manually when operating in icing conditions. (A-06-03 – Urgent)

4.1.3 Transport Canada

Transport Canada (TC) Aircraft Certification and Commercial and Business Aviation maintained contact with the FAA in developing corrective action with the type certificate holder to ensure this model aircraft's compliance with flight into icing as detailed in its type certificate.

TC responded to Recommendation A06-01 on 20 April 2006. In its response, TC stated that, on 24 January 2006, Service Difficulty Alert 2006-01 was issued. Service Difficulty Alert 2006-01R1 was released on 01 February 2006 and the latest revision 2006-01R2 was released on 24 March 2006. TC also reviewed FAA Airworthiness Directive (AD) 2006-06-06 (see Section 4.1.4). TC supports the FAA's determination that these actions are necessary for safe operation. FAA AD 2006-06-06 has been accepted and is mandatory in Canada. Action taken by the FAA will reduce, but not substantially reduce or eliminate, the deficiency raised in Board Recommendation A06-01. Therefore, the response is assessed as Satisfactory in Part. The Board will follow up TC's response to determine to what extent, if any, pilots continue to experience difficulty in operating Cessna 208 aircraft in icing conditions, in light of FAA AD 2006-06-06.

TC responded to Recommendation A06-02 on 20 April 2006. In its response, TC agreed with Recommendation A06-02. TC reviewed FAA AD 2006-06-06 (see Section 4.1.4), accepted the AD and it is now mandatory in Canada. Since TC adopted FAA AD 2006-06-06, this action taken will substantially reduce or eliminate the deficiency raised in Board Recommendation A06-02. Therefore, the response is assessed as Fully Satisfactory.

4.1.4 Federal Aviation Administration

On 16 March 2006, subsequent to the receipt of the TSB recommendations, the FAA issued AD 2006-06-06, effective 24 March 2006. The AD affects Cessna 208 and 208B aircraft, and contains provisions that

- prohibit operators from continued flight after encountering moderate or greater icing conditions;
- define "moderate" icing conditions as one or more of the following conditions:
    - airspeed decreases by 20 knots,
    - engine torque required to maintain airspeed increases by 400 foot-pounds,
    - 120 knots cannot be maintained in level flight, or
    - ice accretion of ¼ inch is observed on the wing strut;
- require changes to the AFM and POH to provide for the following minimum airspeeds in icing conditions (except as required for take-off and landing, and with ground de-icing/anti-icing fluid):
    - flaps up: 120 knots,
    - flaps 10°: 105 knots,
    - flaps 20°: 95 knots;
- require the autopilot to be disconnected at the first indication of ice accretion;
- require changes to the AFM and POH advising that the aural stall warning system does not function properly in all icing conditions;
- require changes to the AFM and POH advising that ice accumulation on the airframe may result in an increase of 20 knots in stall speeds and an increase of 400 foot-pounds in engine torque required to maintain airspeed; and
- require placards to be installed in aircraft cockpits reflecting some of the changes to the AFM and POH.

In its response to TSB Recommendation A06-03, the FAA stated that it agrees with the intent of the recommendation, and has taken action by issuing AD 2006-06-06, which limits the operation of the Cessna 208 and 208B in icing conditions. The response also indicates that the FAA assesses its response as fully meeting the intent of this TSB recommendation.

FAA AD 2006-06-06 will require that pilots exit moderate or more severe icing conditions, when such conditions are encountered. In addition, AD 2006-06-06 provides a definition of icing conditions of moderate or greater intensity as they apply to the Cessna 208 and 208B type, identifies several cues to enable pilots to determine when they must depart such icing conditions, and provides guidance on how to exit icing conditions exceeding "light." Notwithstanding, the results of the FAA flight tests and review of accident data have not demonstrated that a Cessna 208 or 208B can successfully exit from such icing conditions. Effectively, the action taken by the FAA still allows the dispatch of aircraft into forecast icing conditions exceeding "light." The FAA action taken will reduce, but will not substantially reduce or eliminate, the deficiency raised in Board Recommendation A06-03. Therefore, the response is assessed as Satisfactory in Part. The Board will follow up the FAA's response to determine to what extent, if any, pilots continue to experience difficulty in operating Cessna 208 aircraft in icing conditions, in light of FAA AD 2006-06-06. This deficiency file is assigned an Active status.

On 19 May 2006, the FAA indicated that Recommendation A06-04 had been forwarded to the Wichita Aircraft Certification Office for review and evaluation. The FAA Office of Accident Investigation is waiting for a reply from the Wichita Aircraft Certification Office. FAA AD 2006-06-06 was issued to implement the content of this recommendation. This mandatory corrective action specifies the minimum speed in icing conditions of 120 KIAS (knots indicated airspeed) in the flaps up condition, and requires that the pilot depart icing conditions if 120 KIAS cannot be maintained in level flight. Action taken by the FAA will substantially reduce or eliminate the deficiency raised in Board Recommendation A06-04. Therefore, the response is assessed as Fully Satisfactory.

4.1.5 Morningstar Air Express Inc.

Morningstar issued a Caravan Operational Memorandum outlining best practices for Cessna 208 operations. The measures taken include general provisions to allow pilots to cancel flights due to weather conditions, and specific measures to

- prohibit flight in any intensity of freezing rain, freezing drizzle, ice pellets, snow pellets, mixed conditions, and any known or forecast moderate or severe icing conditions;
- require pilots to obtain a graphic area forecast (GFA) before every flight;
- reduce gross weight to 8550 pounds or below in icing conditions;
- require pilots to maintain a minimum of 120 knots in icing conditions; and
- establish minimum ceilings and visibilities for circling approaches in icing conditions.

Morningstar redesigned its Operational Flight Plan and weight and balance form to incorporate a built-in carbon copy to facilitate leaving a copy of this paperwork at the destination as required.

Morningstar carried out an audit to check all aircraft weight and balance documents and confirm accuracy. All Cessna 208 aircraft in the fleet have been reweighed and are on a three-year re-weigh program.

Custom cargo-securing nets have been installed that span the entire length of the aircraft cargo zones in all Cessna 208 Caravans. Flight crew, ramp and loading personnel were trained in the use of the cargo nets. The nets allow for higher zone weights to be used and reduce the possibility that an individual zone weight could be exceeded.

Morningstar adopted a new weight and balance system that determines the aircraft centre of gravity after loading. TC has approved Morningstar's new weight and balance system, which uses a measuring device (the Gelfand System) to determine the length of the front oleo displacement yielding a specific measurement of the actual post-load centre of gravity to ensure that the aircraft is within the required balance envelope.

An additional manager was added to the Flight Operations Department in the role of Assistant Chief Pilot assigned exclusively to the Cessna 208 Caravan operation. The duties include monitoring the operation, ensuring that all pilots follow current safety policies and practices consistently, identifying other possibilities for improving safety, and developing standard operating procedures for the department.

The best practices document was revised in response to the release of new regulatory documents and recommendations from government agencies in Canada and the United States. The following new safety measures were added to this best practices document:

- Circling approaches are prohibited when icing conditions are present.
- No visual flight rules flights are permitted.
- The minimum intersection take-off is 5000 feet.
- A standardized checklist is to be used by all Cessna 208 bases.
- Additional policies, procedures, and restrictions were added for dispatch into known or forecast icing.
- A memorandum was drafted advising all crew to ensure that anti-ice additive is present when refuelling for winter operations.
- A memorandum was issued to all Cessna 208 pilots to ensure that they are physically present (on the ramp beside the loaders) when their aircraft is being loaded by the agent.
- The de-icing boot annual maintenance requirements were reviewed. As a result of this review, the company increased inspection frequency to every six months and scheduled them for the beginning of and during the winter season. The department also added a supplementary inspection order to remove ambiguity for determining a satisfactory test and added a number of other supplementary checks to the previous annual minimum requirements. This new process was carried out on all company Cessna 208 aircraft immediately upon adoption.

- A new dispatch database process was added for tracking and documenting aircraft delays and cancellations due to actual or forecast icing conditions. This database is used to analyse patterns, help in decision making, and report delays and cancellations attributed to icing and weather.

- A Rosemount Aerospace advisory ice-detection system was researched and tested. It was installed on all Cessna 208 aircraft in the fall of 2006.

4.1.6 Cessna Aircraft Company

Cessna revised Supplement S1, Revision 7, to the AFM and POH. Revision 8 of the Supplement incorporated a number of changes from Revision 7. Among other changes, Section 4 was revised to indicate that climbs should be made at 120 knots, and if a climb to get on top of icing conditions is required, a climb of 105 knots is recommended.

4.1.7 Other

The freight company revised the weight of the cargo container, which had been incorrectly noted. In addition, other containers were surveyed to ensure that current and correct weights were listed.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 20 September 2006.

Appendix A – Centre of Gravity Calculations

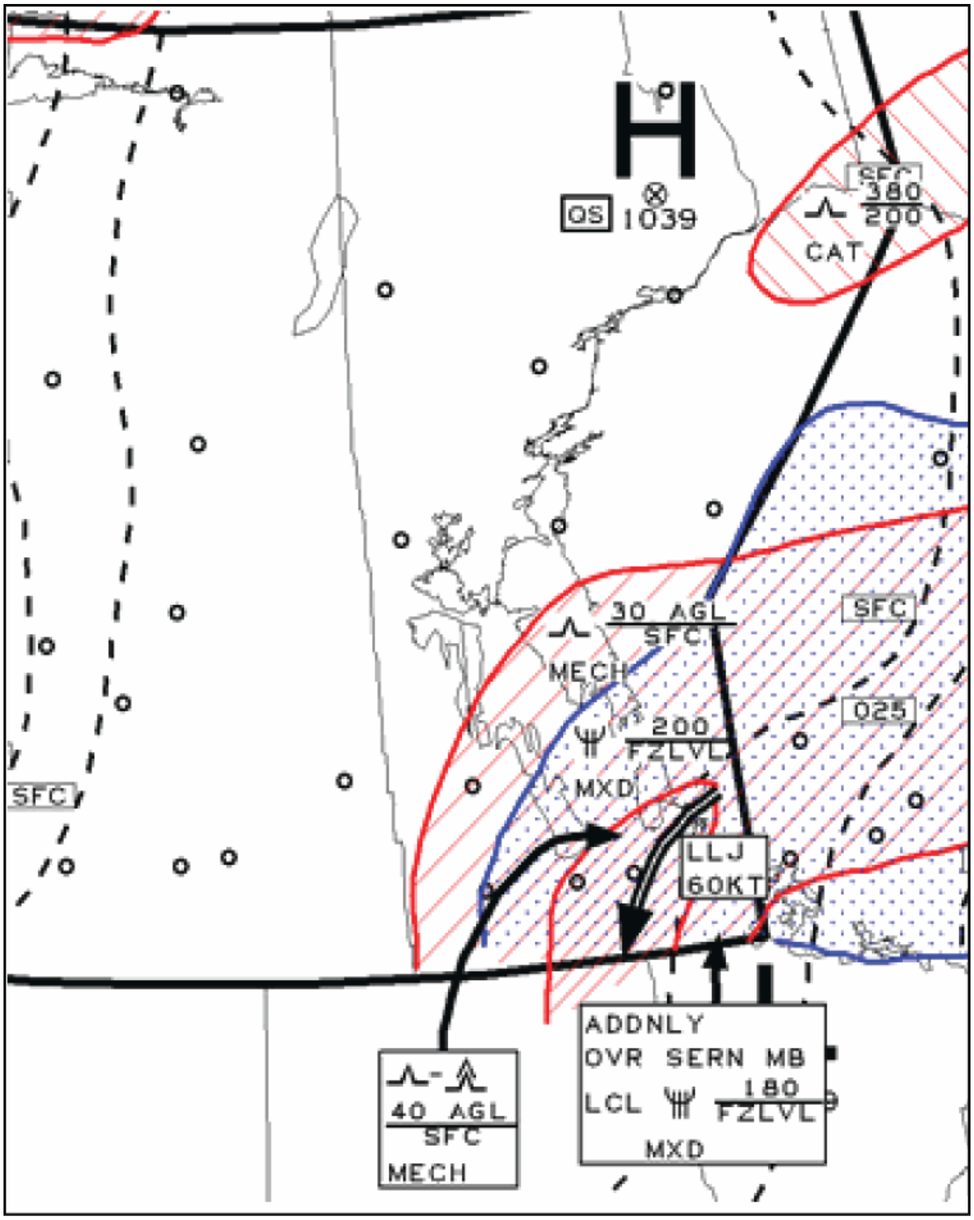
			Most Forward Centre of Gravity		Most Aft Centre of Gravity	
Item		Maximum Weight*	Item Weight*	Item Index	Item Weight*	Item Index
	Zone					
Cabin Cargo	1	415	415	983	264	990
	2	860	860	44	860	44
	3	495	495	71	495	71
	4	340	340	70	340	70
	5	315	164	41	315	80
	6	245				
Pod Cargo	A	230				
	B	310	120	998	120	998
	C	270	80	6	80	6
	D	280				
Pilot Weight			120	985	120	985
Aircraft Basic Weight			4837	438	4837	438
Take-off Fuel			1607	40	1607	40
Gross Take-off Weight			9038	3676	9038	3722
Centre of Gravity			36.2% MAC**		40.1% MAC**	

* All weights are given in pounds.

** MAC – mean aerodynamic chord

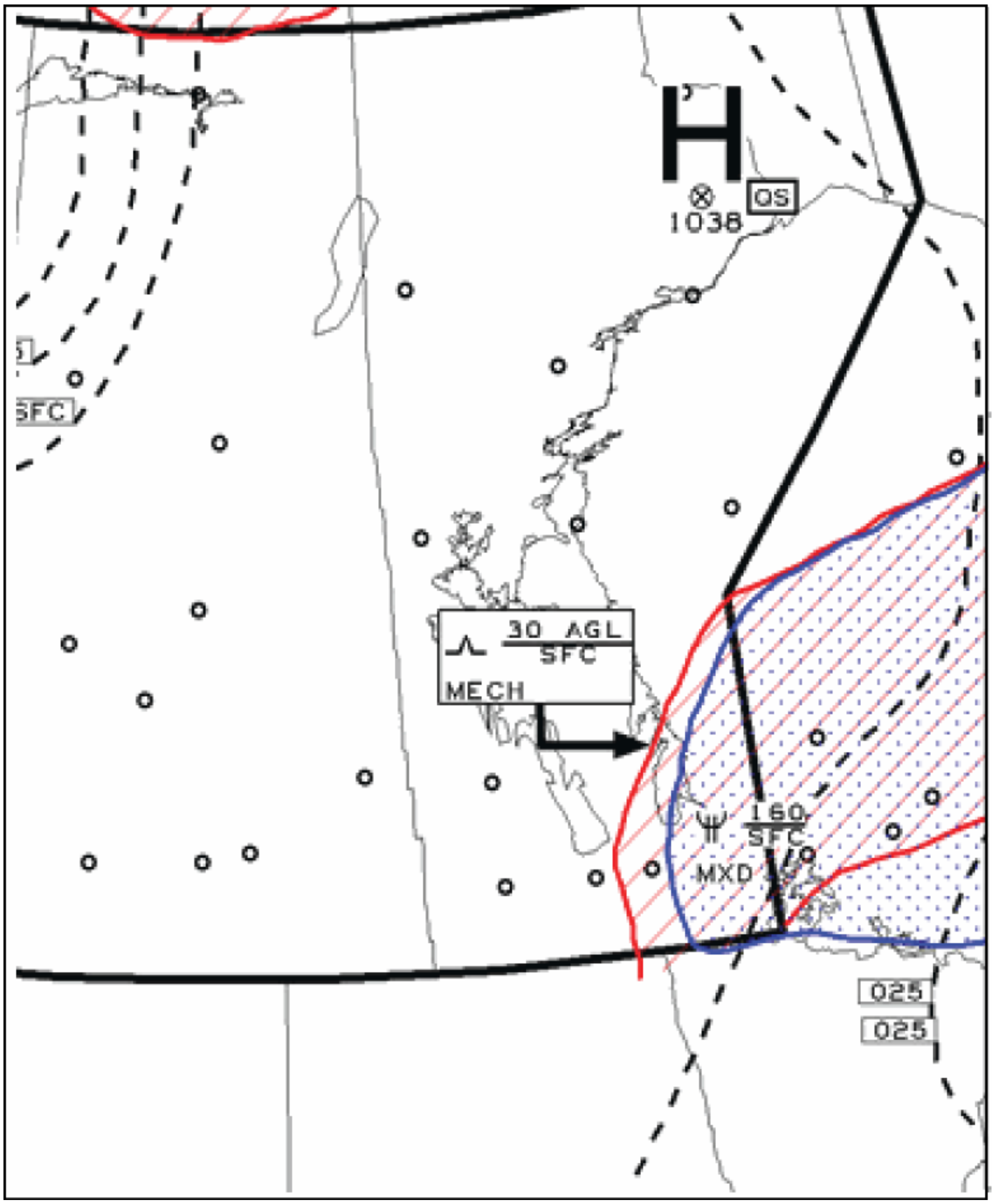
Appendix B – Graphic Area Forecasts for the Route of Flight

Icing and Turbulence, Winnipeg area (valid October 6 at 0600 UTC)



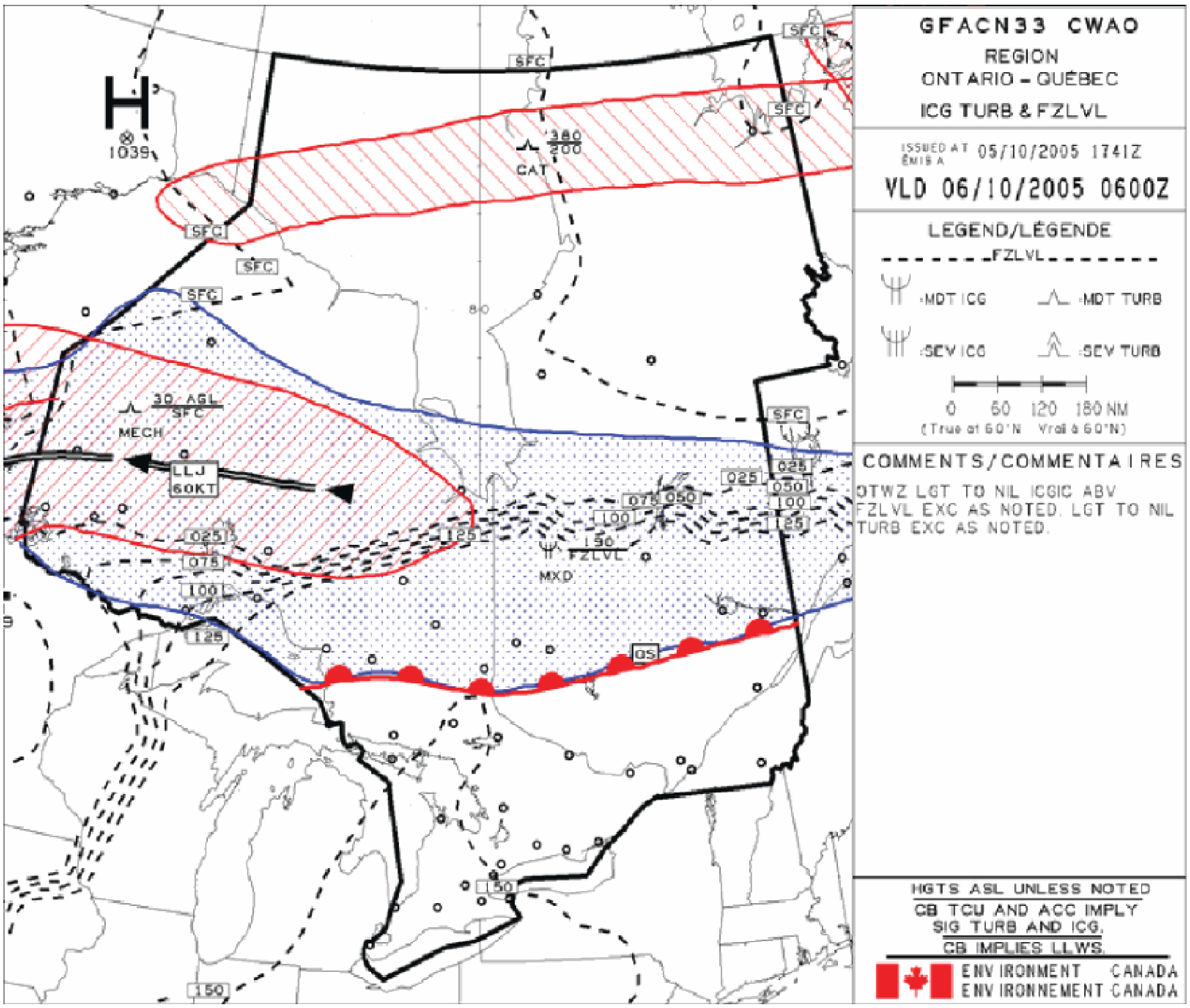
Appendix B – Graphic Area Forecasts for the Route of Flight (continued)

Icing and Turbulence, Winnipeg area (valid October 6 at 1200 UTC)



Appendix B – Graphic Area Forecasts for the Route of Flight (continued)

Icing and Turbulence, northwestern Ontario area (valid October 6 at 0600 UTC)



Appendix C – Icing Parameters

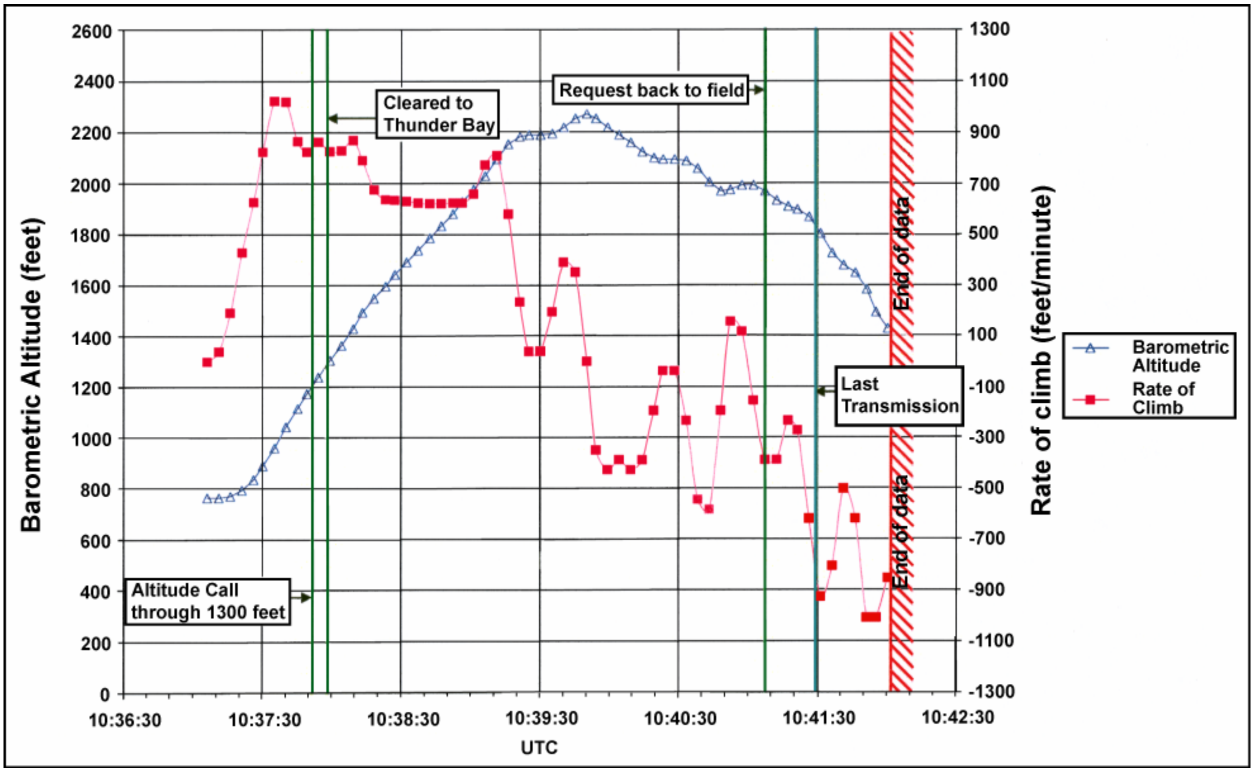
Appendix C to Part 25 of the *Federal Aviation Regulations* (FAR 25) (United States)

(a) *Continuous maximum icing*. The maximum continuous intensity of atmospheric icing conditions (continuous maximum icing) is defined by the variables of the cloud liquid water content, the mean effective diameter of the cloud droplets, the ambient air temperature, and the inter-relationship of these three variables as shown in figure 1 of this appendix. The limiting icing envelope in terms of altitude and temperature is given in figure 2 of this appendix. The inter-relationship of cloud liquid water content with drop diameter and altitude is determined from figures 1 and 2. The cloud liquid water content for continuous maximum icing conditions of a horizontal extent, other than 17.4 nautical miles, is determined by the value of liquid water content of figure 1, multiplied by the appropriate factor from figure 3 of this appendix.

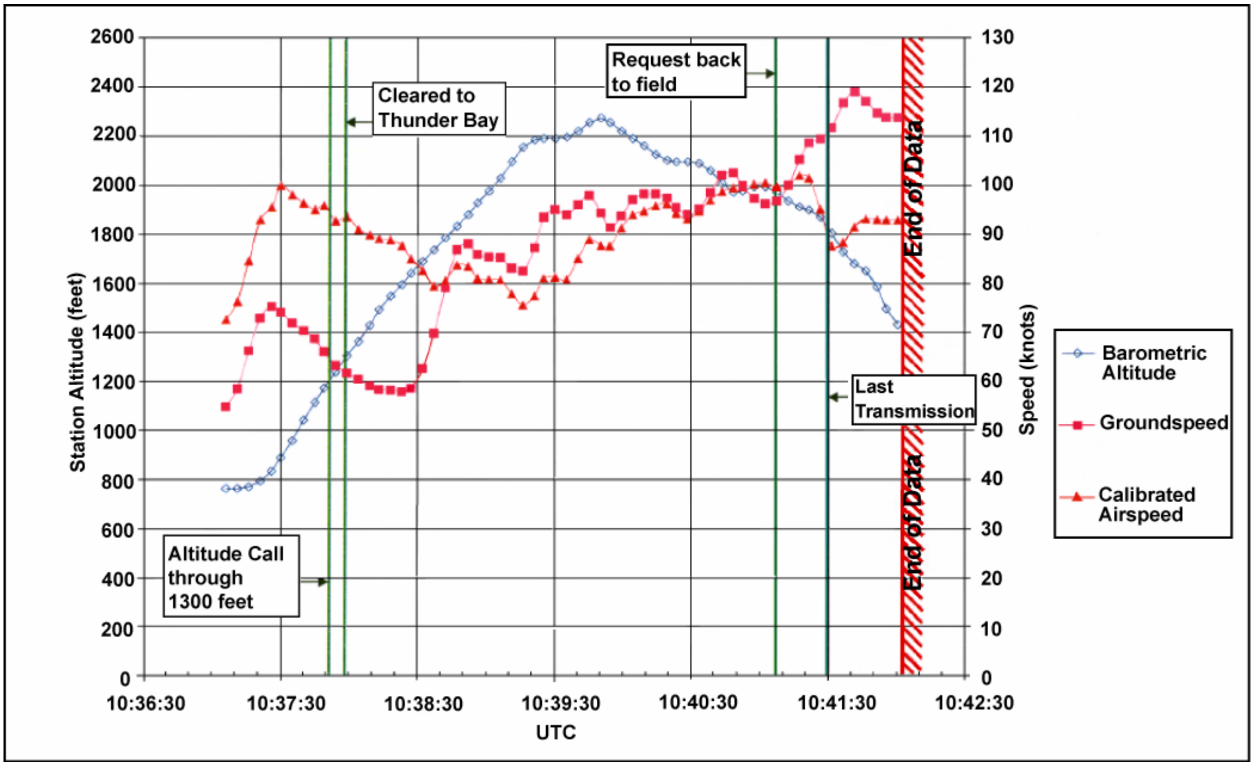
(b) *Intermittent maximum icing*. The intermittent maximum intensity of atmospheric icing conditions (intermittent maximum icing) is defined by the variables of the cloud liquid water content, the mean effective diameter of the cloud droplets, the ambient air temperature, and the inter-relationship of these three variables as shown in figure 4 of this appendix. The limiting icing envelope in terms of altitude and temperature is given in figure 5 of this appendix. The inter-relationship of cloud liquid water content with drop diameter and altitude is determined from figures 4 and 5. The cloud liquid water content for intermittent maximum icing conditions of a horizontal extent, other than 2.6 nautical miles, is determined by the value of cloud liquid water content of figure 4 multiplied by the appropriate factor in figure 6 of this appendix.

The charts referred to in paragraphs (a) and (b) above are available at http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgFAR.nsf/0/1717FB972BCEB08E85256673004F3104?OpenDocument.

Appendix D – Altitude versus Rate of Climb/Descent



Appendix E – Altitude versus Groundspeed/Airspeed



Appendix F – Other Occurrences

On 27 February 1990, at Denver, Colorado, United States, a Cessna 208A was destroyed with one fatality. The National Transportation Safety Board (NTSB) factual report (DEN90FA068) indicates that moderate-to-heavy icing conditions were forecast for the Denver area, freezing drizzle was observed, and the aircraft encountered icing conditions on final approach. The NTSB determined the probable cause of the accident to be "the accumulation of structural ice and subsequent stalling of the aircraft."

On 30 November 1995, at Ardmore, Oklahoma, United States, a Cessna 208B sustained substantial damage and the pilot sustained minor injuries. The NTSB factual report (FTW95FA129) indicates that freezing drizzle was reported at the airport. The aircraft rapidly accumulated ice during the approach, resulting in an inability to maintain altitude and a controlled impact with terrain during an off-airport forced landing. The NTSB determined that "icing conditions prevailing at the destination airport" were a factor in the accident.

On 04 March 1997, at Barrie, Ontario, a Cessna 208B was destroyed with one fatality. The TSB investigation report (A97O0032) indicates that moderate rime icing and moderate mixed icing in light freezing drizzle were forecast, and freezing drizzle was reported in the vicinity of the airport. The TSB made a finding that "ice accumulation on the unprotected leading edge surfaces of the aircraft degraded aircraft performance . . .," and that "the aircraft struck the ground for undetermined reasons."

On 25 November 1997, at North Bay, Ontario, a Cessna 208B sustained substantial damage and two people sustained serious injuries. The TSB investigation report (A97O0247) indicates that light-to-moderate rime icing in cloud and moderate-to-severe mixed icing in freezing drizzle were forecast. The aircraft stalled on final approach. The TSB found that "ice accumulation on the unprotected leading edge surfaces and underside wing surfaces degraded aircraft performance, increasing the stall speed."

On 20 January 1998, at Grand Island, Nebraska, United States, a Cessna 208B sustained substantial damage and the pilot was not injured. The NTSB factual report (CHI98LA084) indicates that the aircraft encountered icing conditions en route. When the pilot reduced power for landing, the aircraft stalled and landed hard. The NTSB determined the probable cause of the accident to be "ice build-up on the airplane's wings and empennage which led to an inadvertent stall and hard landing."

On 05 March 1998, at Clarksville, Tennessee, United States, a Cessna 208B was destroyed with one fatality. The NTSB factual report (MIA98FA091) indicates that light occasional moderate rime icing in cloud was forecast. The aircraft encountered icing conditions, resulting in degraded performance, loss of control, and impact with the terrain. The NTSB determined the probable cause of the accident to be that "the pilot did not maintain control of the airplane due to undetected airframe ice, resulting in an inadvertent stall, and subsequent impact with the ground."

On 07 March 1998, at Bismarck, North Dakota, United States, a Cessna 208B was destroyed with one fatality. The NTSB factual report (CHI98FA119) indicates that the aircraft encountered icing conditions en route, and that a loss of control occurred during final approach, resulting in impact with terrain. The NTSB determined that "factors associated with the accident were the icing conditions."

On 28 April 2001, at Roque Perez, Argentina, a Cessna 208B was destroyed with 10 fatalities. The NTSB preliminary report (MIA01WA133), based on information from the Argentine investigation authority, indicates that conditions aloft were favourable for the formation of airframe icing, and that the pilot requested permission to descend to a lower altitude due to ice formation on the wings.

On 05 May 2001, at Steamboat Springs, Colorado, United States, a Cessna 208B was destroyed with one fatality. The NTSB factual report (DEN01FA094) indicates that occasional moderate rime and mixed icing in clouds were forecast. The aircraft stalled on final approach, resulting in impact with terrain. The NTSB determined the probable cause of the accident to be "an inadvertent stall during an instrument approach, which resulted in a loss of control. Contributing factors were . . . conditions conducive to airframe icing."

On 06 March 2002, at Barrow, Alaska, United States, a Cessna 208B sustained substantial damage and the pilot and four passengers were not injured. The NTSB factual report (ANC02FA020) indicates that severe icing was forecast and that the aircraft stalled on approach. The NTSB determined the probable cause of the accident to be "the pilot's continued flight into adverse weather conditions, and an inadvertent stall. Factors associated with the accident are . . . icing conditions."

On 15 March 2002, at Alma, Wisconsin, United States, a Cessna 208B was destroyed with one fatality. The NTSB factual report (CHI02FA093) indicates that severe mixed and clear icing conditions in clouds and in precipitation were forecast. The pilot encountered icing inbound to an en route stop. The pilot did not have the aircraft de-iced, choosing instead to chip the ice off the aircraft before departure. "The pilot departed with the airplane contaminated with ice, into known severe icing conditions, and was unable to maintain altitude, subsequently impacting trees and terrain." The NTSB determined that one of the factors associated with the accident included the icing conditions.

On 08 November 2002, at Parks, Arizona, United States, a Cessna 208B was destroyed with four fatalities. The NTSB factual report (DEN03FA012) indicates that moderate mixed and rime icing was forecast. The flight encountered icing en route at 15 000 feet and a loss of control and impact with terrain occurred.

On 24 January 2003, at San Angelo, Texas, United States, a Cessna 208B was destroyed with two serious injuries. The NTSB preliminary report (FTW03FA089) indicates that witnesses "observed between 1/4 and 1-inch of ice on the various protected and unprotected surfaces of the aircraft." This investigation is ongoing and no final report is available.

On 29 October 2003, at Cody, Wyoming, United States, a Cessna 208B was destroyed with one fatality. The NTSB factual report (DEN04MA015) indicates that the pilot reported light rime icing at 12 000 feet. A loss of control and impact with terrain occurred. The NTSB determined that an inadvertent stall and the snow and icing conditions were contributing factors.

On 04 November 2003, at Bangor, Maine, United States, a Cessna 208B sustained minor damage and the pilot was not injured. The NTSB factual report (NYC04IA023) indicates that occasional moderate rime and mixed icing in precipitation and clouds were forecast. The flight encountered freezing rain en route, and the pilot requested descent and diversion to Bangor. The pilot "had no forward visibility through the windshield" and the aircraft landed hard on the runway without any landing flare. The NTSB determined that the probable cause of the incident was "the pilot's inability to see through the windshield, which was obscured due to icing conditions. . . . A factor contributing to the accident was the wing icing."

On 06 December 2004, at Bellevue, Idaho, United States, a Cessna 208B was destroyed with two fatalities. The NTSB factual report (SEA05FA025) indicates that occasional moderate rime or mixed icing in clouds and precipitation was forecast, and that an aircraft on approach ahead of the Cessna 208B encountered light-to-moderate rime ice. The NTSB determined that the probable cause of the accident was "the pilot's failure to maintain aircraft control while on approach for landing in icing conditions."

On 19 November 2005, at Moscow, Russia, a Cessna 208B was destroyed with eight fatalities. The Russian investigation is ongoing. Information from the Russian investigative authorities, based on data from the on-board flight data recorder, indicates that the aircraft was in level flight into icing conditions and experienced a reduction in airspeed. The crew lost control of the aircraft at about 102 knots, and an impact with terrain occurred.

On 22 November 2005, near Yellowknife, Northwest Territories, a Cessna 208B was not damaged and the pilot and five passengers were not injured. The TSB occurrence (A05C0217) narrative indicates that the flight encountered icing conditions and degraded performance while diverting en route and climbing to 9000 feet. A loss of control occurred at an airspeed just above 100 knots. The pilot regained control with a loss of about 1500 feet, and the flight returned to Yellowknife. The graphic area forecast indicated light icing; however, moderate mixed icing conditions were forecast in freezing drizzle.

On 22 March 2006, near London, Ontario, a Cessna 208B encountered icing conditions at an altitude of 4000 feet and climbed to 6000 feet, but was unable to avoid the icing conditions (TSB occurrence A06O0076). The de-icing system was activated but was unable to keep up with the rate of ice formation on the wings. Aircraft performance was deteriorating and, at full engine power, the aircraft was unable to climb at 120 knots, at a gross weight of about 7150 pounds. The autopilot was off and the crew noted that the controls had become sluggish. The aircraft diverted to nearby London and the flight crew performed shallow turns when heading changes were required. The aircraft landed safely at the London Airport and continued to destination after the icing conditions had cleared the area. The flight crew had checked the en route weather conditions approximately one hour before take-off and there were no reports of icing conditions for their flight. Several pilot reports (PIREPs) were received from other aircraft (both were de Havilland DHC-8), which also encountered icing conditions in the area. No reports of control difficulties were received from these aircraft.

Appendix G – List of Supporting Reports

The following TSB Engineering Laboratory reports were completed:

LP 110/05 — FDR/Aircraft Performance Analysis

LP 111/05 — Engine Instrument Examination

LP 121/05 — De-Ice Valve Analysis

These reports are available upon request from the Transportation Safety Board of Canada.

Appendix H – Glossary

AD	Airworthiness Directive
AFM	aircraft flight manual
agl	above ground level
asl	above sea level
ATC	air traffic control
ATIS	automatic terminal information service
ATPL	airline transport pilot licence
CG	centre of gravity
CIP	Current Icing Potential
CN	Canadian National
CVR	cockpit voice recorder
FAA	Federal Aviation Administration
FARs	*Federal Aviation Regulations*
FBO	fixed-base operator
FDR	flight data recorder
FIC	Flight Information Centre
FIP	Forecast Icing Potential
fpm	feet per minute
GFA	graphic area forecast
IFR	instrument flight rules
IMC	instrument meteorological conditions
in Hg	inches of mercury
ITT	inter-turbine temperature
KIAS	knots indicated airspeed
MAC	mean aerodynamic chord
MANAIR	*Manual of Standards and Procedures for Aviation Weather Forecasts* (Environment Canada publication)
METAR	aviation routine weather report
Morningstar	Morningstar Air Express Inc.
Ng	gas generator speed
NOAA	National Oceanic & Atmospheric Administration
NTSB	National Transportation Safety Board
PAR	power analyzer recorder
PIREP	pilot report
POH	Pilot's Operating Handbook
PPC	pilot proficiency check
SIGMET	significant meteorological message
sm	statute miles
SPECI	special weather observation
TAF	aerodrome forecast
TC	Transport Canada
TSB	Transportation Safety Board of Canada

UTC	Coordinated Universal Time
VMC	visual meteorological conditions
Vy	best rate of climb airspeed
°	degrees
°C	degrees Celsius
%	per cent